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STRESS CORROSION SUSCEPTIBILITY OF ALUMINUM CARTRIDGE CASES

M. A. Pelensky, et al

Frankford Arsenal
Philadelphia, Pennsylvania

September 1973

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13. ABSTRACT

This report concerns the investigation of stress corrosion cracking of experimental aluminum cartridge cases in a 6 percent sodium chloride boiling solution. The cases (5.56 mm) were of 7475 aluminum alloy, tempered to T6 or T73 condition, and the empty cases assembled with projectiles to represent the stressed condition of finished cartridges.

Stresses applied to the mouth rim and neck of the cases were calculated from the interference, i.e., projectile diameter vs internal diameter of the case mouth and the case neck wall thickness.

For each of three calculated stress levels, a range of failure times was observed. Replicates in excess of twelve were necessary to be assured of failure time and frequency, and the trend of stress corrosion cracking susceptibility. On plotting the results on a log-probability scale (log time to failure/cumulative percent failed) a straight line plot was obtained. Comparisons of the results reveal the T73 cases appreciably less susceptible to stress corrosion failure than the T6 cases, as would be expected.

This method is indicated feasible and reliable as an accelerated means for assessing stress corrosion cracking susceptibility of aluminum cartridge cases.

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TABLE OF CONTENTS

List of Tables

List of Tables - Cont'd

List of Illustrations

INTRODUCTION

This report presents results of investigations of stress corrossion cracking behavior of experimental aluminum cartridge case (5.56 mm) subjected to boiling 6 percent sodium chloride solution. It includes cartridge cases fabricated of 7475 alloy in different heat treated conditions, namely T6 (susceptible) and T73 (less susceptible). Cartridge cases tested for stress corrosion cracking susceptibility were stressed by insertion of production gilding metal projectiles, or aluminum plugs made for this purpose, into the cases. The different metal inserts were included to determine the influence of like and dissimilar metal on cracking failure. Projectiles and cases were selected to provide a range of calculated stress levels from 20 to 80 ksi. (According to specified dimensions for cartridge components, stresses could range from a minimum of approximately 8 ksi to a maximum of 53 ksi).

This work was intended to establish the feasibility and reliability of testing by this method of stressing and the related calculated applied stresses. This work also was intended to determine relationships of variables as applied stress, alloy temper, projectile material, and crimping or lack of crimping of the cartridge case. Supplemental to this investigation of the accelerated method, sets of the aluminum cartridge cases in the T6 condition, and under stresses calculated to be from 50 to 58 ksi, were exposed to industrial, marine, and tropical atmospheric environments.

BACKGROUND

High strength, 7000 series, aluminum alloys may be susceptible to stress corrosion cracking.[1,2] This applies to 7475 in the T6 condition, which when heat treated to T73 should be considerably less susceptible. Whether this effect would follow in cartridge cases was to be determined.

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[1] W. W. Binger, E. H. Hollingsworth, and D. O. Sprowls, Aluminum, Vol. 1, Ed. K. R. Van Horn, Am. Soc. Mets., Ohio, 1967, pp. 235-245.

[2] J. A. Nock, Jr., ibid, pp. 327-329.

The 7475-T6 aluminum alloys being considered for 5.56 mm cartridge case fabrication are potentially susceptible to stress corrosion cracking since it is recognized that cartridge cases are subjected, particularly at the case mouth, to stresses resulting from insertion of projectiles. Applied stresses, based on projectile and case design dimensions, could amount to approximately 70% or 75% of yield stress. (Stresses calculated from drawing tolerances range from a minimum of approximately 8 ksi to a maximum of approximately 53 ksi). Exposure of assembled rounds to various environments, especially marine environments, could feasibly result in stress corrosion cracking of 7475-T6 cases. Methods for application of stresses in determining stress corrosion cracking susceptibility of cast, forged, or wrought forms of commercial aluminum alloys are well defined or standardized (e.g., bent beam, U bend, C ring, tensile). However, these methods are not directly applicable to finished forms of cartridge cases.

Accordingly, investigations relative to stress corrosion testing methods and stress corrosion cracking susceptibility of 7475 aluminum alloy cases were proposed.

MATERIALS AND ENVIRONMENT

The materials and the environmental test conditions involved in this investigation to date are as follows:

Materials

1. 7475-T6 aluminum cartridge cases with 7075-T6 aluminum plugs, uncrimped.
2. 7475-T6 aluminum cartridge cases with gilding metal projectiles, uncrimped and crimped.
3. 7475-T73 aluminum cartridge cases with 7075-T6 aluminum plugs, uncrimped.

Environment

1. Boiling 6% NaCl solution.

EXPERIMENTAL APPROACH

Diameters of the inside of the case mouth and of the plugs or projectiles, and the thickness of the case wall in the vicinity of the mouth, were measured for numerous components. Cases and plugs were paired to obtain desired applied hoop stresses at the case mouth. For these investigations, the stresses were from 20 to 80 ksi.

Applied hoop stresses were calculated using the following equation[3]:

$$^{*}F = I \times E \times ID/OD^2$$

where -

F = desired applied stress
I = interference, inches-projectile diameter minus case inside diameter
E = modulus of elasticity, taken as 10×10^6 psi**
ID = inside diameter of case, inches
OD = outside diameter of case, inches

Residual stresses in the cases are not included in the calculations of applied stress.

*Theoretically, accurate calculation of applied stress will result-if projectiles and cases are perfectly round, and if case wall thickness is uniform.

**Re: ORDP 20-301, p. 1 - For aluminum alloys, E ranges from 9.9 1/10 to 11.4×10^6 psi, usually taken as 10.3×10^6 psi.

Assembled specimens were totally immersed in boiling 6 percent sodium chloride solution, in a refluxing apparatus. The failure time, i.e., first evidence of cracking in the stressed case neck, was noted.

The feasibility and dependability of the approach was conducted with specimens prepared only with anodized aluminum inserts in 7475-T6 cases. Subsequent experiments included studies of the effects of different tempering of the cases and of dissimilar metal (gilding metal clad, jacketed) projectile.

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[3] H. L. Craig, D. O. Sprowls, and D. E. Piper, Handbook Corrosion Testing and Evaluation, Ed. W. H. Ailor, John Wiley and Sons, Inc. New York, 1971, p. 255.

In the preliminary experiments, to study the effects of temper or heat treatment of the cases and the influence of different metal projectiles, on the propensity or incidence of cracking, the cartridge cases employed, had not been crimped. It was intended not to introduce the crimping variable until some preliminary results were acquired. Later, the effect of crimping the cases, performed in an actual production line operation, was introduced and the results of this factor evaluated.

In addition to the above considerations, attention was directed to ascertaining the minimum quantity of replicates which would allow dependable interpretations of the results.

RESULTS AND DISCUSSION

It is appropriate to give some attention to non-uniformities in dimension of case and projectile components, since these unquestionably bear influence on the calculated hoop stress values. The non-uniformities are more pronounced in the cases; less in the gilding metal projectiles; and still less in the machined and anodized aluminum plugs.

Inside diameter dimensions of the case mouth region vary in the range of 0.0002 to 0.0026 inch, as illustrated in Table I, for 20 cases of one production batch, selected at random. This represents the degree of "out-of-round" of the cases. Variations of the outside diameter of the same 20 specimens are presented in Table II. These vary from 0.0004 to 0.0014 inch, and the average difference is 0.0008 inch.

Gilding metal projectiles of normal production vary in diameter by about 0.0002 inch, as shown for 20 specimens in Table III. Oversized gilding metal projectiles purposely acquired for attaining higher stress levels in cases, varied in diameter from 0.0002 to 0.0017 inch, giving an average difference of 0.0006, as presented in Table IV. The aluminum anodized plugs are considerably more uniform in diameter measurement and roundness, as can be seen from Table V. Of 20 specimens randomly selected, the diameters varied at most by 0.0005 inch, with an average difference of 0.0001 inch.

TABLE I.

Variations in Measurements
Case, Inside Diameter

Group	Max	Min	Average	Range
D	.2242	.2230	.2236	.0012
D	.2237	.2234	.22355	.0003
D	.2244	.2226	.2235	.0018
D	.2241	.2232	.22365	.0009
D	.2240	.2232	.2236	.0008
D	.2243	.2228	.22355	.0015
D	.2244	.2225	.22345	.0019
D	.2239	.2234	.22365	.0005
D	.2239	.2231	.2235	.0008
D	.2239	.2231	.2235	.0008
E	.2243	.2225	.2234	.0018
E	.2237	.2234	.22355	.0003
E	.2238	.2231	.22345	.0007
E	.2242	.2224	.2233	.0018
E	.2235	.2233	.2234	.0002
E	.2244	.2218	.2231	.0026
E	.2237	.2227	.2232	.0010
E	.2240	.2226	.2233	.0014
E	.2240	.2226	.2233	.0014
E	.2243	.2221	.2232	.0022

Average of 20, Variation = .0012
Range = .0002 to .0026

TABLE II.

Variations in Measurements
Case, Outside Diameter

Group	Max	Min	Average	Range
D	.2429	.2420	.24245	.0009
D	.2428	.2428	.2426	.0004
D	.2432	.2423	.24275	.0009
D	.2427	.2421	.2424	.0006
D	.2432	.2425	.24285	.0007
D	.2431	.2421	.2426	.0010
D	.2429	.2422	.24255	.0007
D	.2431	.2426	.24285	.0005
D	.2426	.2421	.24235	.0005
D	.2435	.2426	.24305	.0009
E	.2429	.2424	.24265	.0005
E	.2436	.2425	.24305	.0011
E	.2431	.2425	.2428	.0006
E	.2435	.2421	.2428	.0014
E	.2433	.2429	.2431	.0004
E	.2440	.2420	.2430	.0020
E	.2430	.2422	.2426	.0008
E	.2435	.2423	.2429	.0012
E	.2430	.2425	.24275	.0005
E	.2432	.2422	.2427	.0010

Average of 20, Variation = .00083
Range = .0004 to .0014

TABLE III.

Variations in Measurement
Gilding Metal Projectile Diameter
(Normal Production)

Outer Diameter - Normal Production .2239 to .2245

Group	Max	Min	Average	Range
Agm	.2242	.2240	.2241	.0002
Agm	.2242	.2240	.2241	.0002
Agm	.2242	.2242	.2242	-
Agm	.2243	.2240	.22415	.0003
Agm	.2243	.2240	.22415	.0003
Agm	.2243	.2240	.22415	.0003
Agm	.2242	.2241	.22415	.0001
Agm	.2242	.2240	.2241	.0002
Agm	.2242	.2240	.2241	.0002
Agm	.2244	.2241	.22425	.0003
Agm	.2241	.2240	.22405	.0001
Agm	.2243	.2240	.22415	.0003
Dgm	.2242	.2239	.22405	.0003
Dgm	.2243	.2239	.2241	.0004
Dgm	.2242	.2240	.2241	.0002
Dgm	.2242	.2241	.22415	.0001
Dgm	.2242	.2241	.22415	.0001
Dgm	.2242	.2239	.22405	.0003
Dgm	.2241	.2240	.22405	.0001
Dgm	.2242	.2239	.22405	.0003

Average of 20, Variation = .0002
Range = .0000 to .0004

TABLE IV.

Variations in Measurement
Gilding Metal Projectile Diameter
(Oversize)

Outer Diameter - Oversize, Greater than 0.2245

Group	Max	Min	Average	Range
Egm	.2250	.2243	.22465	.0017
Egm	.2249	.2245	.2247	.0002
Egm	.2248	.2244	.2246	.0004
Egm	.2248	.2244	.2246	.0004
Egm	.2248	.2243	.22455	.0005
Egm	.2247	.2243	.2245	.0004
Egm	.2247	.2243	.2245	.0004
Egm	.2248	.2244	.2246	.0004
Egm	.2248	.2244	.2246	.0004
Egm	.2250	.2243	.22465	.0007
Fgm	.2249	.2242	.22455	.0007
Fgm	.2250	.2243	.22465	.0007
Fgm	.2247	.2243	.2245	.0004
Fgm	.2249	.2243	.2246	.0006
Fgm	.2249	.2242	.22455	.0007
Fgm	.2248	.2242	.2245	.0006
Fgm	.2249	.2243	.2246	.0006
Fgm	.2236	.2233	.22345	.0003
Fgm	.2248	.2242	.2245	.0006
Fgm	.2247	.2244	.22455	.0003

Average of 20, Variation = .00055
Range = .0002 to .0017

TABLE V.

Variations in Measurement
Machined, Aluminum Projectile Diameter

Group	Outer Diameter (in.) Max	Min	Average	Range
D	.2242	.2242	.2242	-
D	.2242	.2241	.22415	.0001
D	.2242	.2241	.22415	.0001
D	.2242	.2241	.22415	.0001
D	.2241	.2241	.2241	-
D	.2242	.2241	.22415	.0001
D	.2243	.2242	.22425	.0001
D	.2243	.2242	.22425	.0001
D	.2244	.2243	.22435	.0001
D	.2243	.2243	.2243	-
E	.2255	.2250	.22525	.0005
E	.2254	.2254	.2254	-
E	.2254	.2249	.22515	.0005
E	.2250	.2248	.2249	.0002
E	.2251	.2247	.2249	.0004
E	.2248	.2246	.2247	.0002
E	.2250	.2249	.22495	.0001
E	.2247	.2246	.22465	.0001
E	.2250	.2250	.2250	-
E	.22485	.22475	.2248	.0001

Average of 20, Variation = .00014
Range = 0.0 to .0005

The non-uniformities in dimensions of the cases and projectiles would result in actual applied stresses in the cases different in some degree to those calculated from average dimensions. However, since it was not practical to measure the actual stress in each case, the equation, $F = I \times E \times ID/OD^2$, was the means for calculating a reasonably accurate applied stress. Further, because of the dimensional variations, it was deemed advisable to establish average values for the individual case inside diameter (ID), case outside diameter (OD), and projectile diameter.

Based on some 200 cartridge cases with aluminum plug or gilding metal projectile combinations, the ratio ID/OD^2 in the equation above, for simplification, was taken to be 3.8 (this means that 1 mil interference, I, results in 38,000 psi calculated stress). Calculations involving some 200 cartridge cases (with ID average greater than 0.2227 in.) result in ID/OD^2 ranging from 3.77 to 3.81 or for a one mil interference, applied stress ranges from 37,700 psi to 38,100 psi. An error of 0.0001 in. measurement would result in an error of approximately 3800 psi calculated stress. For this reason, rounding off to 3.8 was for practical purposes considered warranted. Subsequently, actual OD measurements were omitted and only case ID and projectile dimensions were taken to determine interference for stress calculation purposes (using the 3.8 value for ID/OD^2).

DATA COLLECTED

Results of stressed cartridge cases subjected to boiling 6 percent NaCl solution were arranged as follows:

- Table VI - 7475-T6 cases with aluminum plugs, uncrimped
- Table VII - 7475-T6 cases with gilding metal projectiles, uncrimped
- Table VIII - 7475-T73 cases with aluminum plugs, uncrimped
- Table IX - 7475-T6 cases with gilding metal projectiles and crimped after assembly

Times to failure as evidenced by visible cracking of cartridge cases are indicated. Data are arrayed to show this information in ascending order of applied stress.

TABLE VI.

Times to Failure
7475-T6 Cases with Aluminum Alloy Plugs
Uncrimped

Specimens (No. tested)	Stress (psi)	Interference (in.)	Times-to-Failure (hrs.)
8	22,800	.0006	2; 3; 8; 2-8 to 24; 28 to 32; 32 to 96; 31½ to 122
4	24,700	.00065	2; 5; 8; NF 200
6	26,600	.0007	2-3½; 5; 7; 7 to 23; 8 to 24
4	28,500	.00075	3½; 4; 5; 8 to 24
7	30,400	.0008	2-3; 3½; 6; 2-32 to 96; 54 to 96
5	32,300	.00085	1; 1½; 7; 2-8 to 23
4	34,200	.0009	4; 2-8 to 23; NF 100
3	36,100	.00095	7 to 23; 2 NF 144
3	39,900	.00105	8 to 24; 27; NF 100
4	41,800	.0011	1½; 2½; NF 28; NF 102
1	43,700	.00115	NF 102
4	45,600	.0012	1; 1½; 4 to 19½; 6 to 22
4	49,400	.0013	½; 1; 2-7 to 23
5	51,300	.00135	1; 4; 2-7 to 25; 8 to 72
5	53,200	.0014	4; 2-6; 72; NF 174
3	55,100	.00145	1; 4; NF 168
9	57,000	.0015	3-1; 1½; 2-6; 4 to 19½; 7 to 25; NF 168
2	58,900	.00155	1; 4 to 19½
3	60,800	.0016	5½; 6½; 7 to 23
7	62,700	.00165	1; 3; 6; 7½ to 23; 2-8 to 72; NF 1
4	64,600	.0017	2-1; 3½; 7
5	66,500	.00175	1; 4½; 6; 6½; 7½ to 23
3	68,400	.0018	1; 2-2
3	70,300	.00185	2-1; 30½ to 47½
3	72,200	.0019	2-3; 6
4	74,100	.00195	1; 6; 2-7 to 23
4	76,000	.0020	2; 6; 7; NF 148
1	77,900	.00205	1
1	79,800	.0021	7

NF - No failure

TABLE VII.

Times to Failure
7475-T6 Cases with Gilding Metal Projectiles
Uncrimped

Specimens (No. tested)	Stress (psi)	Interference (in.)	Times-to-Failure (hrs.)
2	20,900	.00055	2-8 to 24
3	22,800	.0006	3; 6; 78 to 143
1	24,700	.00065	2
7	26,600	.0007	2-4; 8 to 24; 23 to 26; 78 to 143; 2 NF 143
1	28,500	.00075	2
1	30,400	.00085	NF 143
4	34,200	.0009	6; 7 to 23; 53; 54 to 143
2	38,000	.0010	29; NF 143
6	41,800	.0011	7; 4-7 to 23; 26 to 29
5	43,700	.00115	2; 8; 2-7 to 23; 31
10	45,600	.0012	2-4; 5; 2-7; 3-8 to 23; 54 to 167; 79 to 144
6	47,500	.00125	2-5; 3-7; 8
5	49,400	.0013	4; 5; 3-7 to 24
3	50,300	.00135	2-8 to 24; 55 to 123
2	53,200	.0014	2-7 to 24
1	55,100	.00145	7
3	57,000	.0015	7 to 23; 2-29
2	60,800	.0016	7½; 8-23
3	62,700	.00165	1; 5; 6 to 21
6	64,600	.0017	1; 4; 5; 7; 6 to 21; 30 to 45½
1	66,500	.00175	1
1	68,400	.0018	4
1	70,300	.00185	5
1	72,200	.0019	3
1	74,100	.00195	3
7	76,000	.0020	1; 1; 1; 2; 3; 4; 6
4	77,900	.00205	1; 1; 3; 3
3	79,800	.0021	5; 5; 7 to 23

NF - No failure

TABLE VIII.

Times to Failure
7475-T73 Cases with Aluminum Alloy Plugs
Uncrimped

Specimens (No. tested)	Stress (psi)	Interference (in.)	Times-to-Failure (hrs.)
6	41,800	.0011	NF 102; 5-NF 143
6	43,700	.00115	NF 102; 5 NF 143
2	45,600	.0012	2 NF 143
3	47,500	.00125	2; 2 NF 143
2	49,400	.0013	NF 102; NF 143
3	53,200	.0014	2; 7 to 23; 26 to 71
5	57,000	.0015	3; 7 to 23; 28 to 143; NF 102; NF 143
6	60,800	.0016	23 to 27; 26 to 71; NF 79; NF 102; NF 143; NF 360
1	62,700	.00165	NF 143
4	64,600	.0017	2; 6 3/4; 26 to 71; NF 360
1	66,500	.00175	NF 79
5	68,400	.0018	3; 4; 2 NF 79; NF 143
3	72,200	.0019	3; 76; 102 to 168
1	76,600	.0020	NF 360
5	77,900	.00205	2; 6 3/4 to 22½; 78 to 143; 102 to 168; NF 143
4	79,800	.0021	3; 30 to 71; 2-NF 143

NF - No failure

TABLE IX.

Times to Failure
7475-T6 Cases with Gilding Metal Projectiles
Crimped

Specimens (No. Tested)	Stress (psi)	Interference (in.)	Times-to-Failure (hrs.)
10	22,800	.0006	6; 3-8 to 23; 2-8 to 70; 30 to 95; 54 to 120; NF 71; NF 95
7	24,700	.0065	3; 2-8 to 23; 31 to 47; 2-30 to 95; NF 47
5	26,600	.0007	3-8 to 23; 55 to 71; 30 to 95
3	28,500	.00075	8 to 23; 30 to 95; 55 to 71
1	30,400	.0008	8 to 23
1	32,300	.00035	8 to 23
4	34,200	.0009	8; 2-8 to 23; NF 47
2	36,100	.00095	5; 7
6	38,000	.0010	3; 4; 7; 2-8 to 23; 31 to 48
2	43,700	.0015	4; 8 to 24
1	49,400	.0013	1
2	51,300	.00135	4; 8
6	53,200	.0014	2; 6; 7; 8; 8 to 23; 29
9	55,100	.00145	2-1; 2; 2-4; 2-7; 8 to 24; NF 120
8	57,000	.0015	1; 3; 4; 2-6; 7; 8 to 23; 29
6	58,900	.00155	3-1; 4; 2-6
8	60,800	.0016	2-1; 3; 4; 5; 6; 2-8 to 23
7	62,700	.00165	4; 6; 2-7; 8 to 23; 31 to 48; NF 101
6	64,600	.0017	1; 4; 2-6; 8; 8 to 23
3	66,500	.00175	3; 2-6
1	68,400	.0018	4
2	70,300	.00185	1; 8 to 24
3	72,200	.0019	4; 5; 7
1	74,100	.00195	6
5	76,000	.0020	3; 4; 6; 7; 8 to 70
3	77,900	.00205	6; 2-7
2	79,800	.0021	3; 7

NF - No failure

For statistical evaluation purposes, frequency distributions of times to failure were tabulated and are presented in:

Table X - 7475-T6 cases with aluminum plugs, uncrimped

Table XI - 7475-T6 cases with gilding metal projectiles, uncrimped

Table XII - 7475-T73 cases with aluminum plugs, uncrimped

Table XIII - 7475-T6 cases with gilding metal projectiles, crimped after assembly

Cumulative frequencies and percentage failures also are tabulated in these tables. Note that a two hour time-to-failure class interval was selected to show some regularity in results. (A one-hour interval showed greater irregularity and a three-hour interval resulted in less detail).

In order to evaluate different levels of applied stress with respect to failure times, cases in the T6 temper were examined over the stress range of approximately 20 to 80 ksi. The 80 ksi level should be at or above the ultimate yield stress (ca. 78 ksi) of the alloy. Stressed T6 cases were considered in three general groupings, i.e., ca. 20-39.9, 40-59.9, or 60-80 ksi. For cases in the T73 temper, the stress range employed was approximately 40 to 80 ksi, since low incidence of failure and very long times were experienced at stress levels under 40 ksi. Only two stressed case groupings, i.e., ca. 40-59.9 or 60-80 ksi, were considered for the T73 cases. In addition to the effects of the tempering, other variables, namely, the different projectile metals, the non-crimping or crimping of cases after projectile insertion were included in this examination and analysis. Failure times and frequency to failures, for specimens subjected to the different stresses, are listed as follows:

Table XIV - for T6 cases with aluminum plugs, uncrimped

Table XV - for T6 cases with gilding metal projectiles, uncrimped

Table XVI - for T73 cases with aluminum plugs, uncrimped

Table XVII - for T6 cases with gilding metal projectiles, crimped

Where failures occurred overnight or during weekends, a span of time-to-failure is indicated.

TABLE X.

Frequency Distribution of Failures
7475-T6 Cases with Aluminum Alloy Plugs
Uncrimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)	Survival (%)
0 - 2	28	28	23.5	76.5
2.1 - 4	17	45	37.7	62.3
4.1 - 6	15	60	50.3	49.7
6.1 - 8	9	69	58.0	42.0
4 - 19½	3	72	60.5	39.5
6 - 22	1	94	79.0	21.0
7 - 23	9	94	79.0	21.0
7 - 25	3	94	79.0	21.0
8 - 23	4	94	79.0	21.0
8 - 24	5	94	79.0	21.0
27	1	95	79.8	20.2
30	1	96	80.6	19.4
NF 28	1	97		
8 - 72	3	100		
30½ - 47½	1	106		
32 - 96	3	106	89.0	11.0
31½ - 122	1	106	89.0	11.0
54 - 96	1	106	89.0	11.0
72	1	107	89.8	10.2
NF 100	2	119		
NF 102	2	119		
NF 144	2	119		
NF 148	1	119		
NF 168	4	119		
NF 200	1	119		

NF - No failure

TABLE XI.

Frequency Distribution of Failures
7475-T6 Cases with Gilding Metal Projectiles
Uncrimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)	Survival (%)
0 - 2	13	13	14.2	85.8
2.1 - 4	14	27	29.3	71.7
4.1 - 6	12	39	42.4	57.6
6.1 - 8	11	50	54.3	45.7
7 - 24	25	75	81.5	18.5
25	1	76	82.5	17.5
29	4	80	86.9	13.1
30 - 45½	1	81	87.9	12.1
53	1	82	89.0	11.0
54 - 143	5	87	94.3	5.7
NF 143	5	92	----	----

NF - No failure

TABLE XII.

Frequency Distribution of Failures
7475-T73 Cases with Aluminum Alloy Inserts
Uncrimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)	Survival (%)
0 - 2	4	4	7.0	93.0
2.1 - 4	5	9	15.8	84.2
4.1 - 6	NF			
6.1 - 8	1	10	17.5	82.5
7 - 23	3	13	22.7	77.3
25	1	14	24.5	75.5
26 -71	4	18	31.6	68.4
76	1	19	33.3	66.7
78 - 143	2	21	36.7	63.3
NF 79	4		----	----
NF 102	5		----	----
102 to 168	2	57	----	----
NF 143	22		----	----
NF 360	3		----	----

NF - No failure

TABLE XIII.

Frequency Distribution of Times to Failure
and Cumulative Distribution
7475-T6 with Gilding Metal Projectile
Crimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)	Survival (%)
0 - 2	13	13	11.4	88.6
2.1 - 4	20	33	28.9	71.1
4.1 - 6	18	51	44.8	55.2
6.1 - 8	17	68	59.6	40.4
8 - 24	24	92	80.7	19.3
8 - 70	3	95		
29	2	97	85.0	15.0
31 - 47	3	100	87.6	12.4
30 - 95	5	105		
55 - 71	2	107		
54 - 120	1	108		
NF 47	2	110		
NF 71	1	111		
NF 95, NF 101	2	113		
NF 120	1	114		

NF - No failure

TABLE XIV.

Frequency Distributions at Various Stress Levels
7475-T6 Cases with Aluminum Inserts
Uncrimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)
	20-35 ksi		
0 - 2	4	4	10.5
2.1 - 4	9	13	34.1
4.1 - 6	4	17	44.7
6.1 - 8	4	21	55.2
7 - 24	9	30	78.8
30	1	31	81.5
32 - 122	5	36	94.7
NF 100	1	37	
NF 200	1	38	
	42-57 ksi (incl 41.8)		
0 - 2	11	11	31.4
2.1 - 4	4	15	42.7
4.1 - 6	4	19	54.2
6.1 - 8			
4 - 19½	2	21	60.0
6 - 22	1	22	62.7
7 - 25	5	27	77.0
8 - 72	1	28	79.8
NF 28	1	29	
72	1	30	85.5
NF 102	5	35	
NF 168	5	35	
NF 174	5	35	
	65-80 ksi (incl 64.6)		
0 - 2	11	11	39.1
2.1 - 4	3	14	50.0
4.1 - 6	5	19	67.7
6.1 - 8	4	23	82.0
7 - 23	3	26	92.7
30 - 47	1	27	96.1
NF 148	1	28	

NF - No failure

TABLE XV.

Frequency Distribution at Various Stress Levels
7475-T6 Cases with Gilding Metal Projectiles
Uncrimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)
	20-35 ksi		
0 - 2	2	2	10.5
2.1 - 4	3	5	26.2
4.1 - 6	2	7	36.8
6.1 - 8			
7 - 24	4	11	57.8
24½	1	12	63.0
53	1	13	68.3
54 - 143	3	16	84.0
NF 143			
	42-57 ksi (incl 41.8)		
0 - 2	1	1	2.5
2.1 - 4	3	4	9.8
4.1 - 6	4	8	19.5
6.1 - 8	9	17	41.4
7 - 24	17	34	82.8
26 - 29	3	37	90.0
31	1	38	92.5
55 - 167	3	41	
	65-80 ksi (incl 64.6)		
0 - 2	8	8	32
2.1 - 4	8	16	64
4.1 - 6	5	21	84
6.1 - 8	1	22	88
6 - 23	2	24	96
30 - 45½	1	25	

NF - No failure

TABLE XVI.

Frequency Distribution at Various Stress Levels 7475-T73 Cases with Aluminum Alloy Plugs Uncrimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)
	42-57 ksi (incl 41.8)		
0 - 2	2	2	7.4
2.1 - 4	1	3	11.1
4.1 - 6	NF	-	----
6.1 - 8	NF	-	----
7 - 23	2	5	18.5
26 - 143	2	7	26.0
NF 102	4	11	40.7
NF 143	16	27	----
	65-80 ksi		
0 - 2	2	2	8.7
2.1 - 4	4	6	26.0
4.1 - 6	NF	-	----
6.1 - 8	1	7	30.4
7 - 22	1	8	34.7
26 - 71	2	10	43.4
76	1	11	47.7
NF 79	3	14	60.7
78 - 168	3	17	73.8
NF 143	4	21	----
NF 360	2	23	----

NF - No failure

TABLE XVII.

Frequency Distribution at Various Stress Levels
7475-T6 Cases with Gilding Metal Projectiles
Crimped

Time-to-Failure Class Interval (hrs.)	Frequency	Cumulative Frequency	Failure (%)
	20-35 ksi		
0 - 2	0	0	0
2.1 - 4	1	1	3.2
4.1 - 6	1	2	6.4
6.1 - 8	1	3	9.7
8 - 23	13	16	51.5
8 - 70	2	18	58.0
31 - 47	1	19	61.2
30 - 95	5	24	77.3
55 - 71	2	26	83.6
54 - 120	1	27	87.0
NF 47	2	29	93.4
NF 71	1	30	96.8
NF 95	1	31	
	42-57 ksi (incl 41.8)		
0 - 2	6	6	21.4
2.1 - 4	6	12	42.7
4.1 - 6	3	15	53.5
6.1 - 8	6	21	74.8
8 - 24	4	25	89.0
29	2	27	96.2
NF 120	1	28	
	65-80 ksi (incl 64.6)		
0 - 2	2	2	7.7
2.1 - 4	7	9	34.5
4.1 - 6	8	17	65.2
6.1 - 8	6	23	88.4
8 - 24	2	25	96.1
8 - 70	1	26	96.1

NF - No failure

FACTORS INFLUENCING RESULTS

Because of differences in microstructure between the T6 and the T73 cases, differences in case and projectile dimension variations, the ovality of cases and projectiles, variability of the thickness of the wall of the cases, and surface irregularities attributable to the method of fabrication, it was expected that the stress corrosion cracking results would evidence appreciable scatter. This, in fact, became evident from the test results. With conventional stress corrosion cracking methods, e.g., in which tensile bar or bent beam specimens are used, failure cracking normally results in considerable scatter.[4,5,6] The results obtained in this work also exhibited scatter, which is considered comparable in extent to that experienced under more widely used testing procedures and specimen configuration.

ANALYSIS OF RESULTS

That there is a wide variation in the time-to-failure of stressed cases, is clearly seen in Tables I through IV, in which the data is arranged according to increasing stress. For example, in Table VI (T6 cases, aluminum plugs) there is a wide distribution of failure times, and this holds for each level of applied stress. The cracking failures occurring at the 24.7 stress level are from two hours to no failure after 200 hours; at 57 ksi, from 1 hour to no failure at 168 hours; at 76 ksi from 2 hours to no failures after 148 hours. Data scatter also prevails essentially to the same extent in the situations involving T6 cases with gilding metal projectiles, (Table VII), T73 cases with aluminum plugs (Table VIII), and T6 cases crimped after projectiles were inserted (Table IX).

However, certain tendencies can be determined when the test results are arranged according to frequency distribution of cumulative failures. Reference to the distribution table of 7475-T6 cases assembled with aluminum plugs (Table X) reveals the greatest frequency of

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[4] A. Gallaccio and M.A. Pelensky, Stress Corrosion Testing, STP425, ASTM, Phila., PA, 1967, pp. 99-106.

[5] M.A. Pelensky and A. Gallaccio, ibid, pp. 107-115.

[6] D.O. Sprowls, ibid, pp. 302-312.

failures occurring during the first time interval (0-2 hours). The cumulative distribution of failure times tends to be linear, up to approximately 10 or 15 hours' exposure, when percentage failure is plotted versus the log of time-to-failure (Figure 1). A linear relation between percentage failure and log of time-to-failure is also suggested for the gilding metal projectile (Table XI & Figure 1) up to approximately 8 hours' exposure. The T73 data suggests a straight line relationship even beyond 15 hours' exposure (Table XII & Figure 2).

Comparison of the 7475-T6 cases with aluminum plugs and cases with gilding metal projectiles suggests some difference in results (Figure 1, Tables XIV and XV). However, from statistical analysis, the difference does not appear significant and may be due to chance. The differences between results of the cases not crimped (Table XI) and cases crimped (Table XIII) were not considered significant.

When the T6 cases are compared with the T73 cases (Figure 2, Table XVI) an appreciable difference in results is apparent and is considered significant. The T73 case results show, as expected, a decreased susceptibility to stress corrosion failure.

Plotting of test results on log-probability scale, i.e., log of time-to-failure versus cumulative percent failed (on a Normal Probability Scale) gives a reasonable straight line indicating a log normal type distribution of results (Figure 3). Linear relationships are apparent for the T6 cases with aluminum alloy plugs, with gilding metal projectiles and also the T73 cases (Figures 4 and 5).

From the 7475-T6 case test results, it is apparent that several replicates (7 or 8) are not enough to demonstrate real differences or trends in stress corrosion cracking susceptibility at different stress levels. This may be noted, for example, by comparing the results of 22.8 ksi and 62.7 ksi stressed specimens (Table VI). However, differences in susceptibility can be observed where 28 or more replicates are considered and results arranged by stress groups and by frequency distribution of failures (Tables XIV and XVII). As expected, the higher stress levels result in shorter times-to-failure.

From the 7475-T73 case test results, it is also apparent that several replicates may not be sufficient to demonstrate conclusively, real differences or trends in stress corrosion cracking susceptibility at different stress levels (Table VIII). Differences in susceptibility however, can be observed where 23 or more replicates are considered by stress groups and distribution of failures (Table XVI).

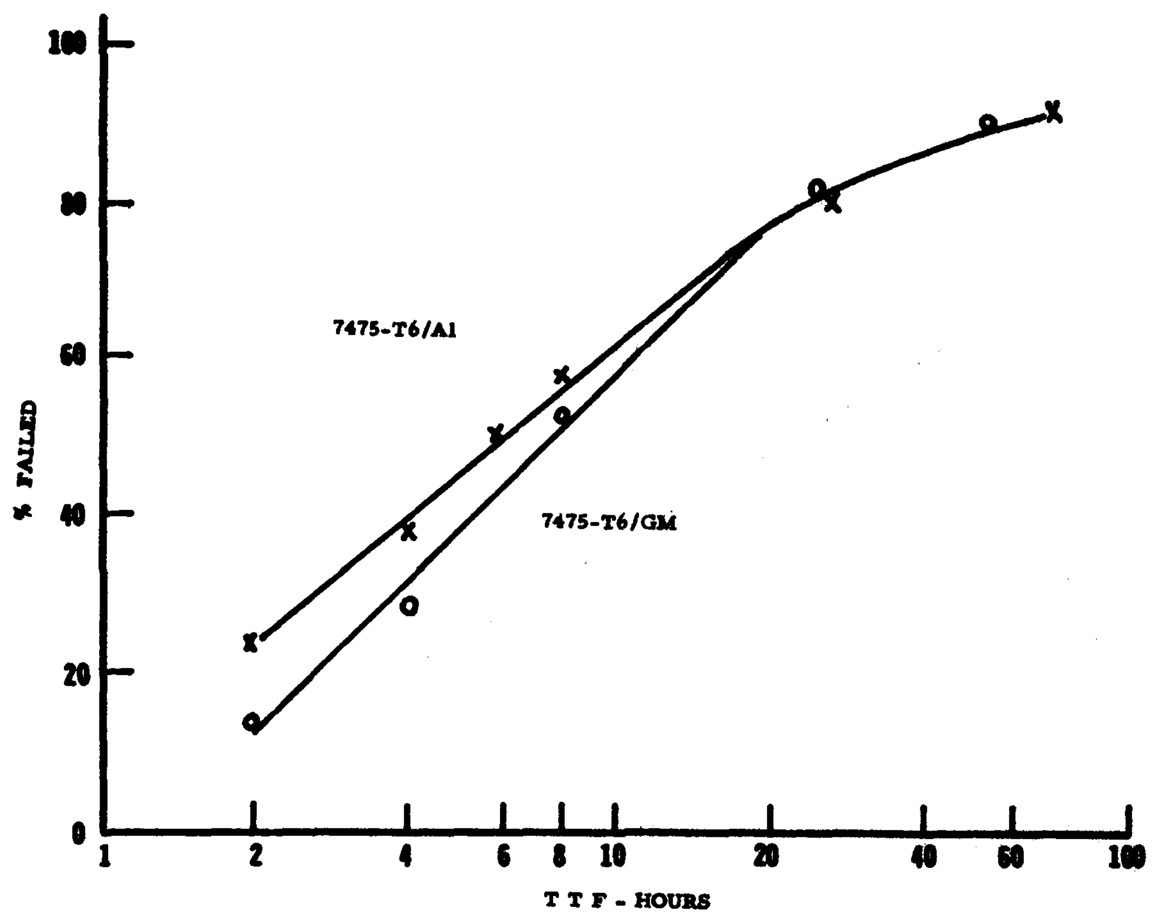

Figure 1. Percent Failed vs Log Time-to-Failure, 7475-T6 Cases, Aluminum Plugs vs Gilding Metal Projectiles

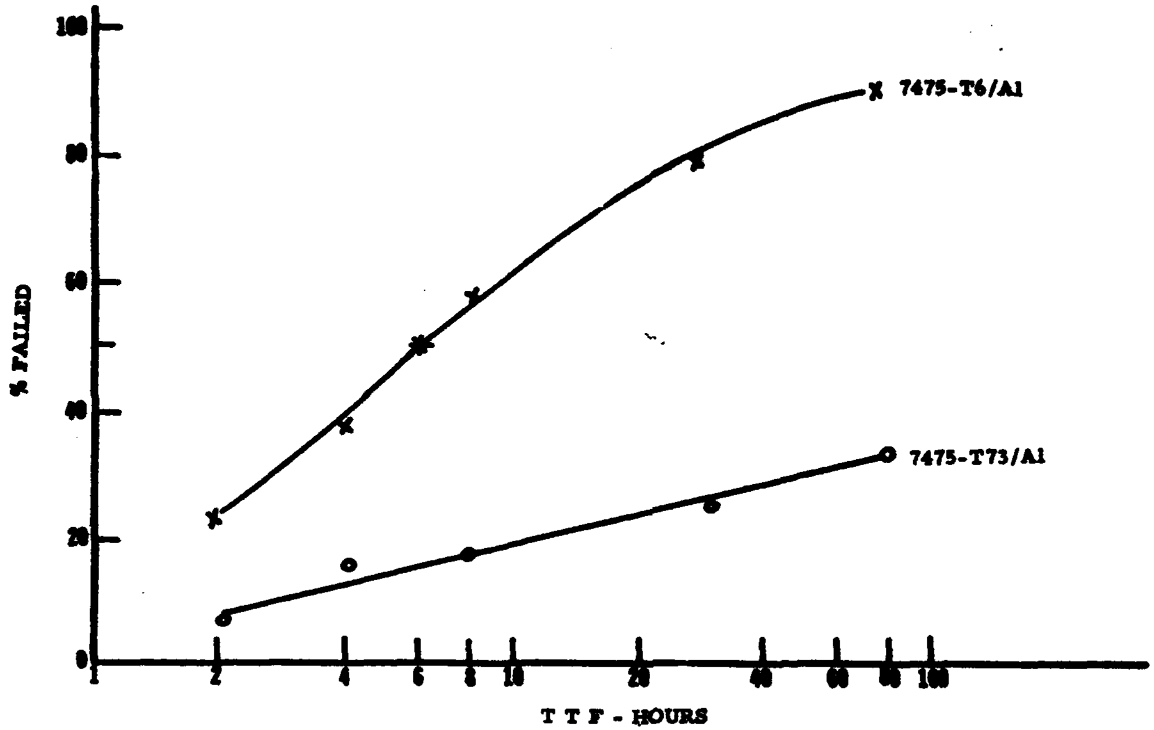

Figure 2. Percent Failed vs Log Time-to-Failure, 7475-T6 vs 7475-T73 Cases

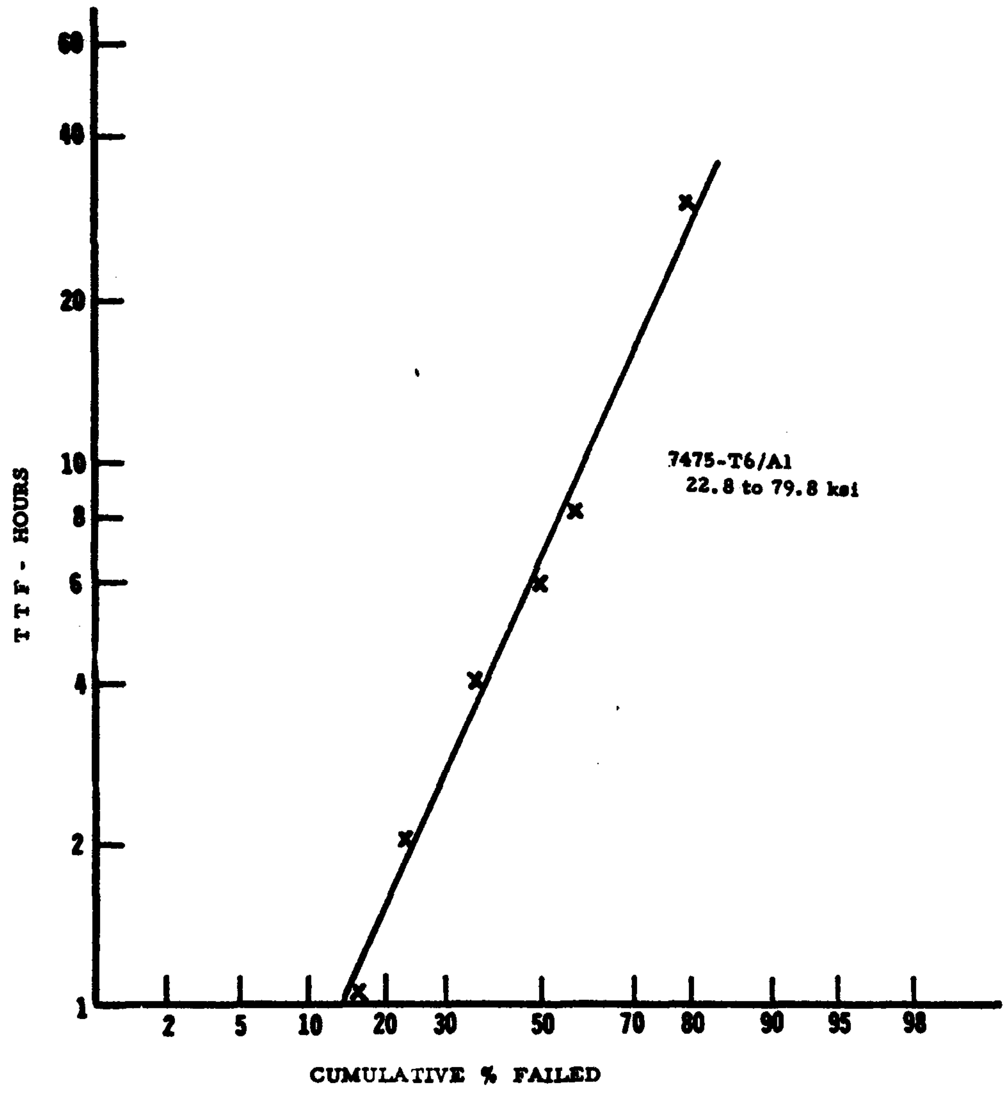

Figure 3. Log Time-to-Failure vs Cumulative Percent Failed, 7475-T6 Cases

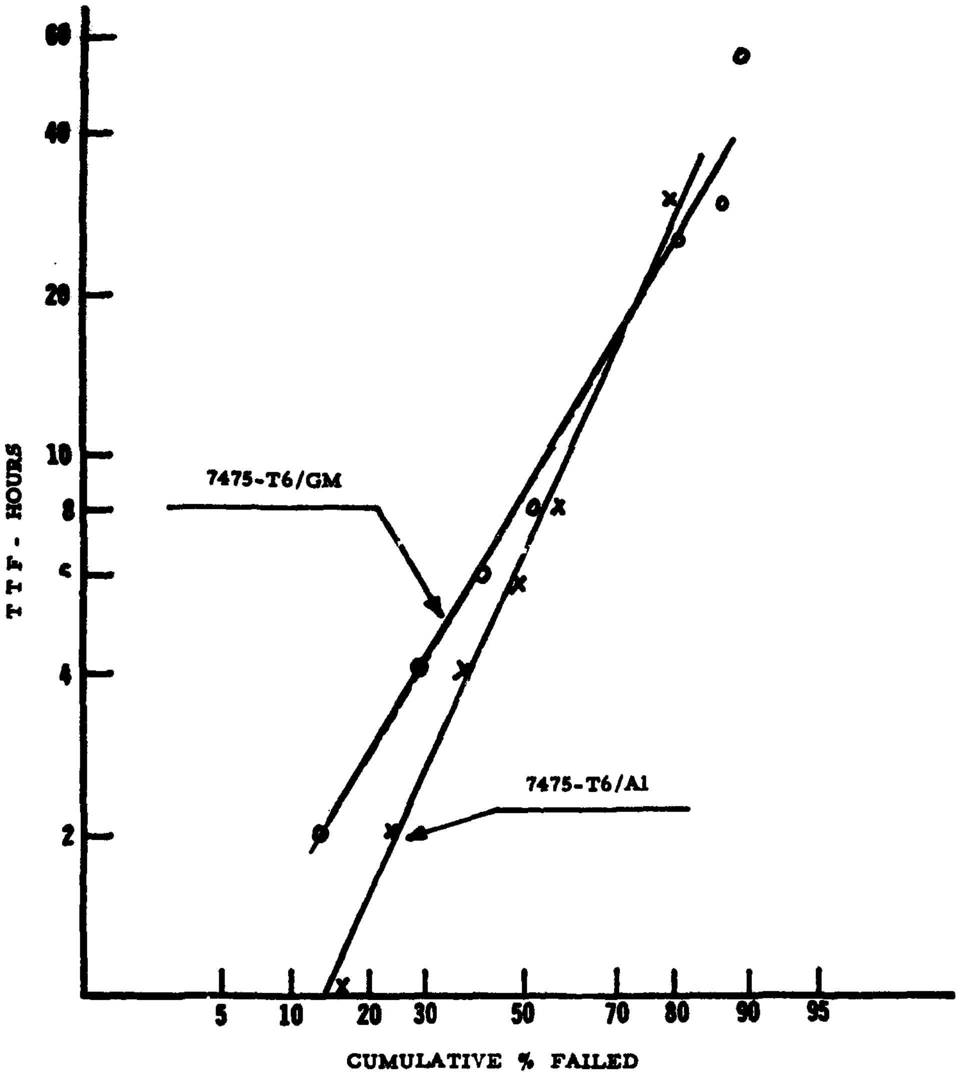

Figure 4. Log Time-to-Failure vs Cumulative Percent Failed, Aluminum Plugs vs Gilding Metal Projectiles, 7475-T6 Cases

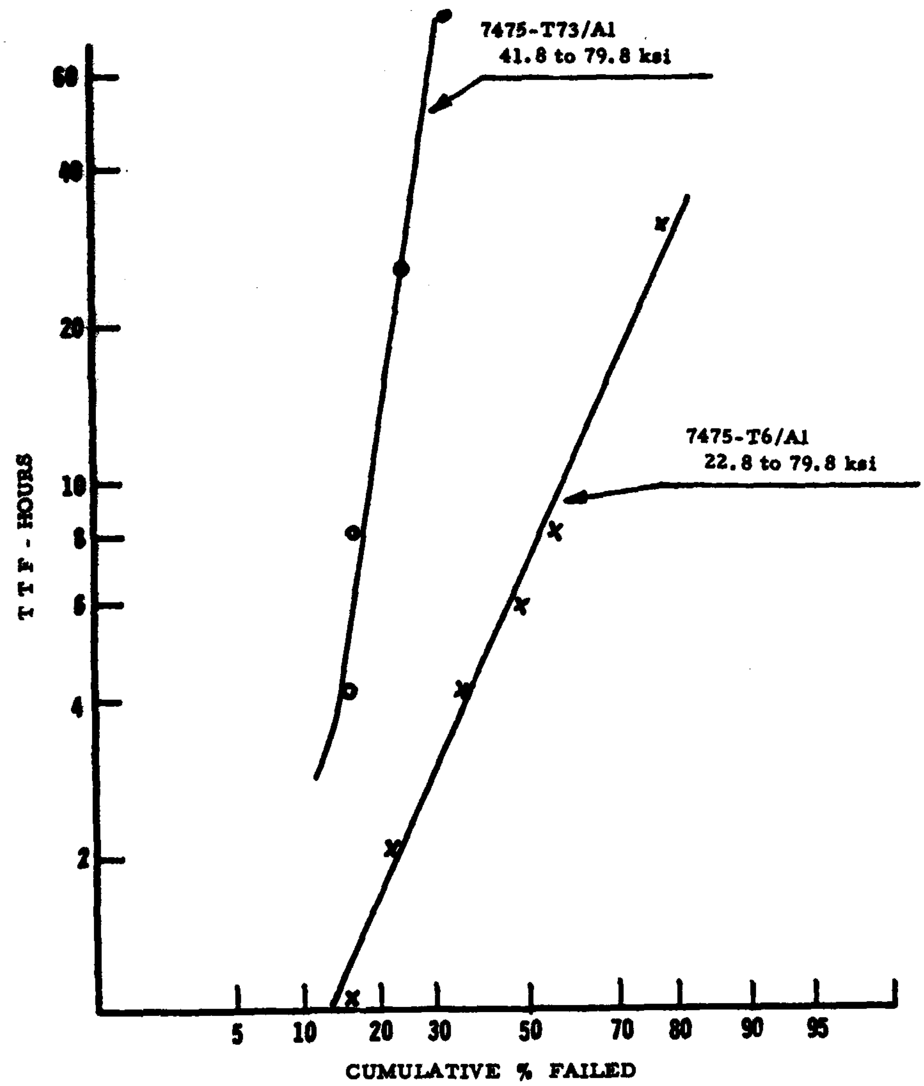

Figure 5. Log Time-to-Failure vs Cumulative Percent Failed, 7475-T6 vs 7475-T73 Cases

CONCLUSIONS

This method for determining the stress corrosion susceptibility of aluminum cartridge cases assembled with projectiles or plugs is considered feasible.

Hoop stresses resulting from assembly of aluminum cartridge cases and projectiles can be approximated from calculations using case and projectile interference measurements.

Even though a relatively large number of specimens (possibly 20 or 30) may be required for testing, the method is considered practicable, since specimens can be taken directly from the production line and no special machining nor other treatment is involved.

As demonstrated from comparison of results of the T73 versus the T6 temper, this method feasibly can be employed for comparing stress corrosion susceptibilities of different tempers of the same alloy. Presumably other alloys also can be compared for stress corrosion susceptibility by this testing method.

The method demonstrates that dissimilar metal coupling of gilding metal projectiles with aluminum alloy cases does not significantly affect stress corrosion susceptibility.

Crimping of cases after projectile assembly does not significantly affect stress corrosion susceptibility.

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5. M. A. Pelensky and A. Gallaccio, ibid, pp. 107-115.

6. D. O. Sprowls, ibid, pp. 302-312.